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PROGRESS IN THE UTILIZATION OF WIND POWER

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16. Abstract Wind power continues to be of interest as a source of energy for isolated locations. In order to distribute the capital costs over many service hours, the wind motors should be able to exploit low wind speeds. Low-speed wind motors can be used only for driving slow machinery. High-speed wind motors to drive small dynamos are now available which are self-starting at low wind speeds. Large-scale wind power stations have not yet passed the experimental stage.

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PROGRESS IN THE UTILIZATION OF WIND POWER

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Small Wind Power Plants /109*

In recent years, the progress in long-distance supply of electrical power, characterized by the expansion of central regional power stations and their distribution networks, has overshadowed the problem of utilization of wind power.

Today, when electricity increasingly dominates and permeates daily life as a cultural factor, utilization of wind power is once again of practical importance. There will always be cases in which obtaining electrical energy through a hookup to the system of a regional power station is out of the question. Here we have in mind only power for isolated farms and structures in high mountains with relatively low power use and duration of use, but which require long and costly connections. The large investment costs of these features completely rule out at the outset economical power supply in view of the expected low consumption of electricity. However, even the smallest and most isolated dwelling requires a cheap source of electricity, even if just for illumination and radio reception.

For such cases, the indicated solution is utilization of wind power, which is available everywhere. However, one must avoid grandiose illusions, since this is not, as often mistakenly assumed, a free source of energy. On the contrary, the cost of generating electricity will never be zero here either, even if the propellant provided by nature -- moving air -- is free.

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* Numbers in the margin indicate pagination in the foreign text.

With wind power as well, one must distinguish between pure operating costs and fixed capital costs. Experience has shown that the construction costs for a small wind power plant can be estimated at about 800 RM [Reichsmark]. For a small wind power plant with a power of 3 kW, this produces the following figures for the energy costs:

Assuming a life of 20 years for the plant and 5% amortization:	
for annual depreciation with an invested capital of 2400 RM	120 RM
5% interest on invested capital	120 RM
cleaner and lubricant	30 RM
maintenance of the plant, restricted to occasional checking of the bearings and lubrication, since the plant operates automatically	60 RM
upkeep and repairs	100 RM
Resulting annual outlay	430 RM

The crucial role of the fixed capital costs in the annual outlay can be immediately recognized, since the capital costs /110 constitute more than half of the total costs. Efforts must therefore concentrate on reducing these capital costs, in order to achieve sufficiently economical operation. The larger the utilization or duration of use of the plant is, the smaller the proportion of the capital costs in the price of the kWh generated will be.

However, in this case, the duration of use is not dictated by the consumer alone, as is usually true. Instead, the duration of use will be determined exclusively by the existing wind conditions. Here, one is dependent on the wind conditions prevailing at the time at the site, and they can vary greatly. In this region, wind intensities of 2-6 m/sec are the norm. Wind conditions are somewhat more favorable at higher elevations, on mountains, and on high buildings projecting above the surrounding ones, as well as on the seacoasts.

Therefore, the objective must be to advantageously exploit the weaker winds as well in the wind motors, and not just the wind intensities from 6 to 10 m/sec.

Only in this way will it be possible to increase the number of hours of use, with which the economic feasibility of wind power plants stands or falls.

For the average plant, if we assume that it operates at full load for an average of 1300 hours per year, the generating costs come out to

$$\frac{430 \times 100}{3 \times 1300} = 11 \text{ Rp}^{1}/\text{kWh.}$$

Therefore, they are not considerably higher than the costs with a hookup to the distribution system of a regional central power station under the usual hookup conditions.

If the profitability of a wind power station is to be increased, the objective must be to increase the number of hours of use. This can be achieved by building a wind motor which also makes it possible to utilize low wind intensities, which, as analysis of weather statistics indicates, are particularly prevalent here during the course of the year. Thus, the efforts of construction firms for wind motors should be concentrated in this direction. In general, we can distinguish between:

low-speed motors. Their method of operation is principally based on the pressure action of the wind. For this purpose, they

[1] [Translator's note: Rp. = Reichspfennig.]

have a large vane surface, and are especially suitable for exploiting light winds to about 4 m/sec. They come into consideration only for driving such slowly running machines as pumps, water engines, saws, etc.

high-speed motors. Only these are suitable for directly driving the wind dynamo, since, in this case, power-draining gearings and transmissions can be eliminated. In their mode of operation, high-speed motors represent the reverse of the air propeller, in that the vane of the wind motor, through its revolution, extracts mechanical energy from the moving air. It was the recently deceased "old master" of wind-motor construction, Major Bilau, ret., who was the first to point out the special importance of efficacious design of high-speed motor vanes in a streamlined shape and correct design of the cross sections between the vanes for allowing the air to flow through. Thus, Bilau created the wind-motor vane he called the "repeller" with which he obtained a power increase by a factor of 2.87 over the previous vanes.

Formerly, a considerable drawback of the high-speed motor was that, when it was stopped, it did not start by itself with the normal vane position. By providing the previously sharp-edged vanes of his repellers with a specially "tailored" jacketing, which he called "ventikanten," Bilau achieved automatic starting at a wind velocity as low as 1.8 to 2 m/sec. In this way, the light winds prevalent in our region can be exploited, thus improving the number of hours of use.

However, for times of no wind or lulls, which are particularly frequent at points close to the ground and can be prolonged, there must always be appropriate reserves, as in the form of an accumulator battery, to bridge such periods without loss of power.

Thus, the good development possibilities for small wind power plants cannot be denied, since there is a marked demand for electrical power because of its universal utility. This has been promptly recognized, e.g. in the United States, since such small wind power plants are often the only power source for radio reception on isolated farms there. The number of such small wind power plants there is already quite large. Hence, the expansion of this special machine industry is also extraordinarily great. This can be seen from the rising overseas export figures -- in these countries, there is usually no chance to obtain power from the network of a central power station. Considerable attention /111 has been devoted to utilization of wind power in Russia as well, as the erection of such plants, especially for agricultural irrigation purposes, adequately demonstrates. Expanded employment of such plants has not yet come about, and such larger construction plans largely exist only on paper.

Large Wind Power Plants

Development in this area is considerably behind that of small wind power plants. The large wind power plants which have been erected up to now are basically experimental plants, and there is no information at all, or at least no reliable information, on their practical operation. The expectations associated with the erection of large wind power plants are frequently exaggerated. This particularly applies to statements that they will be able to replace coal consumption in our energy budget. The proportion of coal consumption going for generation of electrical power is relatively small in comparison with the remaining coal consumption for transporation, residential heating, foundries and iron works, chemical industries, etc. A large reduction in overall coal consumption cannot be expected to result from the general introduction and utilization of electricity from wind power; at most, the reduction would be about 10%.

Utilizing wind power to generate electricity is valuable not for its momentary effect on the coal balance, as it presently stands, but rather because it creates a new branch of industry, and thus produces further possibilities and prospects for the further development of this technology.

The construction of giant plants, such as that planned by Honnef, with towers at least 250 m tall, is still today a leap into the unknown. Before this takes place, an experimental plant with a vane diameter of about 30 m should first be built, in order to first determine the most favorable vane profile. Nevertheless, the skeptical remark of Bilau in his work on "Generation of electricity through giant wind power plants," in ETZ 18 (1935) is no longer quite true, due to the great technical progress which has been made in the meantime. Bilau stated: "My experiments on the utilization of wind power over the last 15 years have convinced me of one thing: Generating electricity on a large scale from wind is structurally impossible and uneconomic. None of the giant plans have been carried out, and none could have been carried out."

For his giant wind power plant, Honnef proposes the use of a ring generator with a pair of wheels turning in opposite directions, by which he achieves twice the peripheral speed obtained with a stationary armature. With an armature diameter of 120 m (!), the air gap is to be only 1.5 cm (cf. [1, 2]). Here, the most favorable diameters of 40-60 m are calculated for an air gap of 22.5 m.

In the existing wind power plant in Balaklava (Crimea), the vane diameter is 30 m, and the axle 25 m from the ground. The power is 100 kW at a wind intensity of about 10.5 m [sic]. It was constructed in 1930/31 and has remained in continuous operation since then.

A more recent example is the wind power plant set up in the Great Mountains, about 16 km west of Rutland (USA) at an elevation of about 600 m. (A more detailed description is found in [3], based on an article in Elec. World 14 (1941)).

Here, the alternating-current generator has a power of 1000 kW at 2300 V and 60 Hz. The current generated is transformed to 44 kV and thus operates in combination with a neighboring regional system. The rate of revolution is 600 rpm, which is transmitted by the two-blade propeller through a hydraulic clutch and a toothed-wheel gearing running in oil. Diameter of the propeller: 52.5 m. Weight of a stainless-steel propeller blade: about 6.9 t; 19.5 m long and 3.3 m wide.

The weight of the complete revolvable mechanism is about 75 t, and the rate of revolution of the propeller is about 30 rpm. The angle of inclination of the propeller balde is automatically controlled in accordance with the current wind speed with the aid of a servomotor, as in the Kaplan turbine. It is reported that the United States plans to build a large number of these electrical wind power plants in various locations, in order to ensure at least the most vital power requirements in the event of war, even if the large regional plants are disturbed.

It is obvious that only special types of construction come up for consideration in this case. We have already referred to the construction difficulties which are involved with giant wind power plants in the discussion of the ring generator proposed by Honnef. Here, Honnef envisioned the use of a synchronous alter- /112
nating-current generator.

In the Kleinhenz wind power plant project, two two-armed cranes are used to attach two sheels each (diameter 60 m) to a 250-m-high tower. At the top of the tower is a fifth wheel. The hubs of the windwheels are designed so that they accommodate in their interiors two direct-current generators driven through toothed wheels, where either just one or both of the generators can be switched in, depending on the wind speed.

Instead of a synchronous alternating-current generator, the employment of an asynchronous alternating-current generator is also conceivable. It has a simple construction in common with the asynchronous alternating-current motor. However, this presupposes a source of a master frequency, in the form, e.g., of a hookup to the distribution network of a central alternating-current power plant.

The use of an asynchronous induction generator does imply a poorer power coefficient, but this is no insurmountable obstacle. The use of sliding-contact capacitors offers the possibility of some improvement.

Voltage Regulation

Variations in wind speed will cause variations in the rate of revolution of the generator, and this will produce corresponding voltage fluctuations. In order to avoid them, special wind dynamo constructions must therefore be considered, which must be characterized by the fact that they deliver constant voltage in spite of the variable rate of revolution. Such special dynamos for direct current have long been known. They work best with an armature excitation.

In [4], Scheufer and Ivanov likewise described a direct-current generator for constant voltage for small wind power plants (for a report, see [5]). The objective was achieved in this case not via an armature reaction, but by using two exciter windings on the pole shank, where the one magnet winding was parallel to an Ohmic resistance with a nonlinear characteristic.

Outlook

If one considers the previous development of wind power utilization, it can be seen that there was a halt in further development in the centuries following the invention of the primitive utilization of wind power using windmills. Finally, modern progress in technology, as illustrated by the development of the automobile and aviation, and which went hand in hand with the expansion of the theory of fluid dynamics and wind-tunnel studies and the information obtained from them, has also led to fruitful developments in the utilization of wind power.

It is characteristic of the spirit of research and invention that this successful development has not stopped even during the present war. For instance, the Reichsarbeitsgemeinschaft Windkraft (RAW) has set itself the objective of researching and treating all questions involved with the utilization of wind power as an energy source for general economic purposes.

The RAW has already done considerable engineering work. For instance, there is as yet hardly sufficient information on wind currents, i.e. on the duration of wind currents of constant or variable velocities and directions in the elevations of over 200 m required for the construction of wind power plants. Serving this purpose are long-term observations using automatically recording devices, which are installed at great heights (e.g. on radio towers).

Only when there is absolute clarity on wind currents in high regions can the construction of wind power plants on heights be undertaken with prospects for success. The studies conducted with the support and promotion of the RAW in this direction have already provided very valuable preliminary research. On this firm foundation of science and research, the solutions of the problem of utilizing wind power will be built successfully in the future.

It would be a serious error to assume that the progress in utilization of wind power will not at all influence the energy balance of those countries blessed with rich water power. On the contrary, they will also benefit from this development, particularly when they have no available coal.

Only in this way will the human settlements in isolated high mountains of some countries be able to acquire a rich and especially a cheap source of energy which they have had to do without, thus forcing them to forego the advantages of a comprehensive exploitation of electrical power.

Summary /113

In places which are too far from electric supply systems, the utilization of wind power will even today be a matter of some interest. Although the wind itself need not be paid for, the energy generated by it is not entirely free of charge, since the interest on the invested capital, as well as the payoff rates, upkeep, etc. have to be reckoned with. In order to distribute these fixed charges over as many service hours, i.e. as many kWh as possible, wind motors must be aimed at which will work even at very low air speeds, which are available nearly all year round. Where no other power station is near, an accumulator battery will have to be provided which will be able to supply energy when no wind is blowing.

Low-speed wind motors utilize the pressure of the moving air on comparatively large blades. Because of their low speed, they can only be used for driving relatively slow machinery. High-speed wind motors, which generally use a kind of propeller similar to that in general use on airplanes, can of course directly drive small dynamos. Special propellers working with a relatively high efficiency and starting at low air speeds are now available.

Large-scale wind power stations have not yet passed the experimental stage. An existing Russian wind power station with an output of 100 kW at 10.5 m/sec air speed has a wheel 30 m in diameter, the axis of which is situated 25 m above ground level. In a mountainous region of the U.S.A., a power station of 1000 kW exists which works in parallel with a hydroelectric power station. The wheel diameter of this wind motor is 52.5 m.

Future wind power stations will no doubt make use of the very high air speeds available at heights over 200 m above ground level.

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